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The Relative Effectiveness of Single-Sex and Coeducational Schools in Thailand

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Single-sex schooling is more effective for girls, but coeducational schooling is more effective for boys in improving student performance in mathematics. The differences are due to peer group effects, rather than to school or classroom characteristics.

Several studies of the relative effectiveness of single-sex and coeducational schools have shown that single-sex secondary education promotes both academic achievement and orientation, particularly for girls. "Single-sex" education also includes coeducational schools where students are separated into single-sex classes for instruction.

Most studies of single-sex education have made little or no attempt to control for factors such as student background, school type (public or private), and school selection by parent or students. These factors can affect achievement and skew analyses that seek to compare only the effect of single-sex education versus coeducation.

Mathematics test scores of Thai eighth-graders, obtained during the 1981-82 academic year, are compared for students in coeducational and single-sex schools. The study overcomes the methodological problems by holding constant student background, school type, and school selection. Moreover, the study minimizes the effects of non-measured variables such as a student's ability, motivation, or previous achievement. It does this by measuring performance at the beginning and again at the end of the year to focus on the educational "value added" during that year.

Girls in single-sex Thai schools scored higher in mathematics achievement at the end of the eighth grade, but the reverse was true for boys, who exhibited higher scores in coeducational schools. Why was this so?

The largest factor affecting student performance was the student's peer group. The data did not permit an analysis of how peer groups affect achievement, but studies in developed countries suggest that class participation and leadership opportunities are suppressed for girls in coeducational settings and for boys in single-sex settings.

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INTRODUCTION

The relative effectiveness of single-sex versus coeducational schools on student attitudinal and cognitive outcomes has become a question of considerable interest for educators in both developed and developing countries. Whereas coeducation is seen as improving educational efficiency (Woody, 1920) and promoting positive social development for students (Dale, 1969, 1971, 1974; Schneider & Coutts, 1982), recent studies suggest that single-sex education has strong positive effects on student achievement and self-perceptions, particularly for girls (Carpenter, 1985; Finn, 1980; Hamilton, 1985; Hennesy, 1985; Jones & Shallcrass, 1972; Lee & Bryk, 1986; Price & Rosemier, 1972; Riordan, 1985). In developing countries where coeducation may be culturally unacceptable, single-sex education holds the additional promise of enabling or increasing female school participation (Lycette, 1986).

Contemporary literature on the effectiveness of single-sex versus coeducational schools, however, suffers from several problems of methodology, interpretation and analysis. The most important methodological issue is the difficulty in attributing differences between the attitudes and cognitive abilities of students in single-sex versus coeducational schools to school characteristics alone, since a variety of non-school factors also affect achievement. These include socio-economic background, innate ability and individual motivation. Moreover, these non-school factors also affect school choices made by families, such that students with one type of background and ability attend single-sex schools, while students with different backgrounds and abilities attend coeducational schools. Unless non-school factors are controlled appropriately, estimates of school effects will be contaminated by what has become known as "selectivity bias." In general, research on the effects of single-sex versus coeducational schools has failed to control for differences in students selecting the two types of schools. We are aware of only two recent studies, both of which utilize data on Catholic schools in the United States (Lee & Bryk, 1986; Riordan, 1985), that make an attempt to control for entry level characteristics of students attending single-sex versus coeducational schools; neither of them directly address the issue of selectivity bias.[1]

A second shortcoming of the available literature is that the causal mechanisms underlying the differences in schooling outcomes for single-sex and coeducational schools have not been analyzed. What do single-sex and coeducational schools actually do that is different? Do they employ different input-mixes or use the same input-mix differently? Is the single-sex school or classroom responsible for the apparent effect? How does the presence or absence of opposite-sex peers change the nature of classroom interchange or the amount of student effort directed towards academics?

Third, the vast majority of previous analyses of single-sex/coeducational school differentials have utilized cross-sectional data only, which does not allow for a direct measure of value added. If the achievement relationship (i.e., the educational production function) holds at both points in time, it is possible to concentrate on exactly what happens educationally between those points when outcomes are measured. Differences in achievement can be related to specific material inputs and teaching processes over a shorter time period.

Moreover, the effect of omitted unmeasured factors, such as student ability or motivation, are lessened in the "value added" as opposed to the "level" formulation. Any "level" effects of these unmeasured variables have already been incorporated into prior (e.g., at the beginning of the school year) achievement. This does not mean that unmeasured variables no longer affect the estimating equation. However, their effect is mitigated because only "growth" effects of omitted variables such as innate abilities would influence "value added". Technically, the error term of a "value added" equation does not contain unmeasured personal characteristics that affect achievement similarly in both periods.

This paper contributes to the literature on single-sex/ coeducational schooling in several important dimensions. First, it extends the empirical evidence for developing countries by analyzing data from the Second International Mathematics Study (SIMS) conducted by the International Association for the Evaluation of Educational Achievement (IEA) in Thailand during the 1981-82 academic year. We are not aware of any other rigorous comparisons of single-sex/coeducational schools in determining achievement in developing countries, although one descriptive study was conducted in Jamaica (Hamilton, 1985).

Second, to our knowledge, this is one of the first comparison studies, in developing or developed countries, of single-sex/ coeducational achievement that uses longitudinal data. (See Lee & Bryk, 1986, for a just published analysis using U.S. data.) In SIMS, students were tested at the beginning and end of the eighth grade school year. We are thus able to obtain better controls for unmeasured variables because the data base contains a direct measure of "value added" of a year of schooling.

Third, the paper also confronts the difficult methodological questions that have arisen in other studies. An individual's status as single-sex or coeducational school student is a choice made by student and parent. If this choice is systematically correlated with personal characteristics, there may be sample selection bias. We model the effect of student and school characteristics on "value added", (i.e. gains in achievement over time) as well as control statistically for the possibility of selection bias.

Fourth, we make further inquiries into the nature and single-sex/coeducational differentials in school achievement. In particular, we document differences in the availability and use of school-inputs between single-sex and coeducational schools, and examine the effects of peers on achievement prior to drawing conclusions about effectiveness.

BACKGROUND

Education in Thailand

With a population of approximately 50 million and a size of 514,000 square kilometers, Thailand is one of the larger countries in Southeast Asia, and is nearly the size of France in both population and land area (World Bank, 1986) The present education system includes six years of primary school, followed by three years of lower secondary education and three years of upper secondary education.[2] Approximately 13% of primary students are enrolled in private schools. The main types of private schools are Chinese, Muslim and Thai; a few international and religious schools also operate.

Government guidelines for curricula and syllabi are followed in all schools, both government and private, although foreign language instruction is more widely available in private schools than in public ones. In Grade 8, four periods of mathematics and four periods of science per week are compulsory; of the 35 total hours per week available, other compulsory subjects are Thai language (4 hours), social studies (5 hours), physical education (3 hours), art education (2 hours), various personality development activities (2-5 hours) and work and occupation (4 hours). Secondary education is selective, with admission dependent upon examinations taken at the end of Grade 6.

Although western-style education in Thailand dates from King Chulalongkorn's modernization efforts in the latter part of the 19th century, formal schooling dates from the thirteenth century. For 600 years, education was based on monastic schools situated in Buddhist temples; it concentrated on teaching boys reading, writing and religion, and girls were not educated (Buripakdi and Mahakhan, 1980).

The introduction of Western education in Thailand changed much of the character of the former education system. One important aspect of change was the inclusion of girls; as early as 1921 the Thai government introduced a Compulsory Education Act, which by 1932 covered in theory 80% of the country. Girls appear to have been included significantly from the outset. For example, in 1965, less than 50 years after the Compulsory Education Act, 82% of primary aged boys and 74% of primary aged girls were enrolled in school. By 1984, 7.3 million students were enrolled in primary schools and 2.3 million students were enrolled in secondary schools; primary education was virtually universal, although only about 30% of the relevant age group attended secondary school (Unesco, 1987). At both primary and secondary levels, females comprise more than 40% of the students (48% in primary in 1980 and 42% in secondary in 1970, the last year for which published data are available). A study of determinants of school participation in rural Thailand confirms this apparent gender equity in schoooling; this study of 400 households in 22 villages found that sex was not a constraint to education participation (Cochrane and Jamison, 1982).

While female education is widespread, and coeducation tolerated where alternatives are not available, single-sex education is apparently preferred for girls, particularly at the secondary level. Thus, "old" Thai, Chinese and other middle-class families typically choose to send their daughters to single-sex Catholic schools operated by nuns. One explanation given for this preference is the opportunity for students to study English more intensively than in the public secondary schools.

Single-sex education

The evidence regarding the effectiveness of single-sex education in general is limited, and research examining its effectiveness vis-a-vis mathematics achievement, per se, is rare. Moreover, since single-sex education is in most cases inextricably confounded with private education generally and Catholic education in particular, most research on its effectiveness has been confounded by selectivity with regard to sector.

Nevertheless, there is growing evidence that single-sex education at the secondary level promotes both academic achievement and orientation, particularly for girls, when compared with mixed-sex education. In this paper, we use the term "single-sex education" to include both single-sex schools and single-sex classes within coeducational schools. We do this because academic achievement is the outcome of interest, and there is evidence that single-sex classes can function effectively to improve female achievement within coeducational environments (Fox, 1976; Harvey,1985). If gender-related socialization were the outcome of interest, we would treat single-sex schools separately from single-sex classes.

Academic achievement. There is considerable evidence that single-sex education is positive for girls; its effects on boys is mixed. Where all-male and all-female schools are grouped into "single-sex" schools, no effects are frequently observed. For example, a school-level study from Thailand (Coomber and Keeves, 1973) found no single-sex/coeducational school effect for science achievement of 14-year-old students

When all-female schools are distinguished from all-male schools, however, positive effects for girls are typically found.

For example, a second study of achievement in southeast Asia surveyed 89 secondary schools and 7,674 students in West Malaysia (Beebout, 1972). In this study, a "value addded" approach was used, with performance indicated by student-level differences between secondary school entrance and completion examination scores; no other student-level characteristics were examined, and analyses were conducted with schools as the unit of analysis. The results showed that students in all-female schools outperformed those in coeducational schools in English and outperformed those in both all-male and coeducational schools in Malay.

Both of the two previous studies analyzed data at the school level, and made little made attempt to control student background or public/private sector, which--in light of recent research on the relative effectiveness of private schools in comparison with public schools--is a serious shortcoming. We are aware of only one large-scale study that compares the effects of single-sex and mixed-sex education, while controlling for student background and sector. This is a recent reanalysis of High School and Beyond data from the U.S. by Lee and Bryk (1986), who controlled for sector by selecting from the data archive 1887 students enrolled in 75 Catholic schools only (21 all-male, 24 all-female and 30 coeducational). Unlike most studies of single-sex education, Lee and Bryk also made extensive adjustments for background characteristics of students. Even controlling for sector and adjusting for student background, the effects of single-sex education on achievement were particularly strong for girls. Specifically, girls in single-sex Catholic schools gained more in reading achievement and science achievement than girls in coeducational Catholic schools; no differences in achievement were observed for boys.

Similar results for girls were found by Riordan (1985) in a reanalysis of National Longitudinal Study data from the U. S. on white students in 1212 public and 37 Catholic school who were enrolled in college, business and general education tracks. This study, however, did not control for sector. Instead, comparisons were made between the performance of girls in Catholic single-sex schools and girls public coeducational schools. In this case, sector differences are undoubtedly partially responsible for the significant single-sex effect that was observed.

Failure to take into account sector and student background may also account for results of studies in which female performance in single-sex schools is not superior to that of students in coeducational schools. For example, Carpenter (1985) studied a stratified random sample of 1286 Grade 12 students in 26 schools in Queensland, Australia. Comparisons were made between girls in non-Government single-sex schools (N = 75) and in Government coeducational schools (N = 428). No differences in overall academic achievement were found, but sector effects were not controlled.

In a related study of girls in single-sex and coeducational schools in Queensland (N = 503) and Victoria (N = 632) Australia, Carpenter and Hayden (1987) found that with paternal occupation and education and maternal education held constant, the sex composition of the school had a positive effect on girls' average external public examination score in Victoria but not on girls' teachers' grades in Queensland. This study, however, included students in public, private and Catholic schools, with no allowance made for sector.

Other studies make no mention of sector and little attempt to control for student background; most report superiority of single-sex education. One such recent study comes from Jamaica (Hamilton, 1985). In this stratified random sample of 1146 Grade 11 students (529 boys and 617 girls) attending 15 of the 41 high schools in Jamaica (3 all-boy, 5 all-girls and 7 coeducational), students in single-sex schools significantly outperformed their same-sex counterparts in coeducational schools on the General Certificate of Education "O" level examinations. In mathematics, in particular, the mean score of girls in single-sex schools was 5.2, compared with a mean of 3.9 for girls in coeducational schools; since the standard deviation of these scores was quite large (s.d = 6.6 for single-sex schools and 3.4 for coeducational schools) these differences were not statistically significant).

A secondar analysis of IEA data from three countries came to the same conclusion regarding the superiority of single-sex schools in promoting achievement. Finn (1980) studied 14-year old students in the United States (4 all-male schools, 4 all female schools, 118 coed schools), England (19 all-male schools, 28 all-female schools, 88 coed schools) and Sweden (95 coed schools). In the U.S. and England, both girls and boys in single-sex schools outperformed their same-sex counterparts students in coeducational schools on a variety of tests, including tests of reading comprehension, word knowledge, biology, chemistry and physics. Effects were stronger for Grade 9 students than for Grade 8 students, and not all effects were statistically significant.

Finally, a study comparing the effects of single-sex <u>classes</u> with those of single-sex <u>schools</u> controlled for background effects by matching students on verbal reasoning scores (Harvey, 1985). In this study, science achievement of students in 17 secondary schools in southwest England was examined; results showed that: (a) girls in single-sex science classes in mixed-sex schools outperformed girls in mixed-sex classes in mixed-schools in physics, but not in biology or chemistry, and (b) girls taught in mixed-sex schools (mixed or single sex classes) outperformed girls taught in single-sex schools in physics and chemistry, but not in biology.

Overall, however, the evidence suggests that girls in single-sex schools do outperform girls in coeducational schools, but with few exceptions, the previous literature does not clarify whether this is due to differences in sector and selectivity of single-sex and coeducational schools. The same comment applies to most studies of non-cognitive outcomes.

Academic orientation. Recent studies have demonstrated the positive effects of single-sex schools on student attitudes and orientations toward academic activities. For example, in the study by Lee and Bryk described above, girls in single-sex Catholic schools took more mathematics courses, spent more time on homework than their peers in coeducational schools, and reported greater interest in mathematics. Positive effects were found for boys with respect to homework and mathematics course-taking only. Similarly, Jones, Shallcrass and Dennis (1972) studied 1,223 New Zealand secondary school students in two single-sex schools and one coeducational school. In comparison with students in the coeducational school, both boys and girls in single-sex schools reported spending more time on homework outside school and preferring to spend an extra hour of school studying rather than doing something else; girls in single-sex schools were more likely to want to be remembered as a brilliant student in comparison with girls in coeducational schools.

Similar results come from Canada. Schneider and Coutts (1982) studied 2029 Grade 10 and Grade 12 students from five coeducational, four all-female and four all-male high schools. They found that in terms of contributing to status among their same-sex peers, students ranked "getting high grades, honor roll" more highly in single-sex schools than in mixed-sex schools.

Finally, in the study by Carpenter and Hayden (1987) mentioned above, girls in single-sex schools in Victoria were more likely to be taking science courses as seniors than were girls in coeducational schools, suggesting that motivation toward science might be higher.

Why are single-sex schools effective?

What explanation does previous research provide for the greater effectiveness of single-sex schools, particularly for girls? Three explanations have been offered: differences in resources available within the schools, differences in governance and organizational characteristics, and differences in classroom "climate" for girls (see Arnot, 1983; Spender and Sarah, 1983; Lee and Bryk, 1986 for recent reviews). In addition to these, we add sector and selectivity; that is, students enrolled in single-sex schools may come from more advantaged backgrounds than those from coeducational schools, since a higher proportion of single-sex schools are in the private sector.

The only study that has examined either differences in resources or differences in organizational characteristics was the Catholic school study reported above (Lee and Bryk, 1986). They found little support for the claim that differences in either accounted for the single-sex school effect. That single-sex learning environments--either single-sex classes or single-sex schools--could benefit girls in particular is strongly suggested by research on classroom interaction that shows diffences in male and female participation rates in class. The majority of this research has been conducted in the United States and Canada, but the findings appear quite stable. It suggests that girls in mixed-sex classes have less opportunity to learn, both from their teachers and from classmates, than do boys in mixed-sex classes. First, in coeducational mathematics classes, teachers direct more of their attention to male students (Leinhardt, Seewald & Engel, 1979); in part, this may be due to greater disruptive behavior on the part of boys (Lockheed, 1984). Second, while girls in mixed-sex classes are equally likely to provide information to male or female classmates, boys are less likely to help their female classmates than their male classmates (Webb, 1982). This combination of less teacher attention and less peer help for girls in coeducational classes could account for the differences in learning observed.

In this paper, we will be able to examine the differential effects of resources and some organizational qualities, but will not be able to examine classroom interactional effects.

THE BASIC MODEL AND DATA

Model

In this paper we use the following final estimating form:

$$(1) \quad A_{i8} = g_o + g_1 A_{i7} + g_2 X_{i8H} + g_3 Z_i + e_{i8}$$

This is a basic value added model where A_{it}--t = 7,8--represents the achievement score of the i^{th} child at the end of year t; X_{i8H} represents a vector of variables measuring the i^{th} child's learning environment during 8^{th} grade; Z_i represents a vector of variables affecting achievement but which are invariant over time; e_{i8} is a random error term and the g's are parameters to be estimated. This basic value added model is derived from more complicated models of the level of achievement, as outlined in the Appendix. The interpretation of the estimated parameters depends crucially upon the assumption of the "level" models. In our version, g_1 is interpreted as the rate at which the impact of seventh grade characteristics affects eighth grade achievement; g_2 is the current period effect of a contemporaneous variable (e.g., parental encouragement during eighth grade) on achievement; and g_3 is the cumulative effect of a fixed variable (e.g., parental background) on eighth grade achievement.

There are several remaining methodological issues which require further discussion. First, note that it is important to distinguish between variables that change during the eighth grade (and thus belong to the X vector) and those that are invariant over the child's schooling career (and thus belong to the Z vector). The coefficient of a Z-type variable (such as sex) cannot be interpreted as the marginal effect on eighth grade achievement; rather, the coefficient is the marginal effect on eighth grade achievement less its effect on achievement in the seventh grade.

Second, the estimate of f might be biased if (1) is estimated by OLS because one of the explanatory variables, A_{i7} has a random component. We do not believe that this is a major problem that would greatly affect the results regarding differential achievement of single-sex and coeducational schools, since both types of schools would be equally affected.

Third, the use of "value added" does not necessarily make the problem of omitting unobserved variables go away -- although we would expect the problem to be mitigated. The problem is important if variables such as ability and motivation are correlated with the X's and Z's (e.g., more able children are given more attention at school and at home). The coefficient of the measured variable would be biased upward or downward, depending upon its correlation with the unmeasured characteristics.

Since we are focusing on one particular environmental effect --the single-sex/coeducational dimension -- the problem can be couched in terms of selection bias. If students are systematically selected (or self-selected) into one type or school or another on the basis of some unobserved criteria (such as ability), estimates of achievement within each school type would be contaminated by this selection effect. This problem is corrected using (now) standard statistical techniques.

Sample

The IEA SIMS sample comprised 99 mathematics teachers and their 4030 eighth-grade students and was derived from a two-stage, stratified random sample of classrooms. The primary sampling units were the twelve national educational regions of Thailand plus Bangkok. Within each region, a random sample of lower-secondary schools was selected, with replacements. At the second stage, a random sample of one class per school was selected from a list of all eighth grade mathematics classes within the school. The resulting sample represented a 1% sample of eighth grade mathematics classrooms within each region. This paper reports data from the 3265 students for whom complete data were available.

At both the beginning and end of the school year, students were administered a mathematics test covering five curriculum content areas (arithmetic, algebra, geometry, statistics and measurement). Students also completed a short background questionnaire at the pretest and a longer one at the posttest administration. Teachers completed several instruments at the posttest, including questionnaires on their backgrounds, teaching practices and characteristics of their randomly selected "target" class. Data about the school were provided by a school administrator and were supplemented by additional information provided by the Ministry of Education.

Mathematics achievement

The IEA developed five mathematics tests for use in SIMS. One of the tests was a forty-item instrument called the core test. The remaining four tests were thirty-five item instruments called "rotated forms" and designated A through D. The five test instruments contained roughly equal proportions of items from each of the five curriculum content areas, except that the core test contained no statistics items

(Wattanawaha, 1986). For purposes of this analysis we regard the instruments as parallel forms with respect to mathematics content.

The IEA longitudinal design called for students to be administered both the core form and one rotated form chosen at random at both pretest and posttest. In Thailand, students were pretested using the core test and one rotated form. At posttest, students again took the core test and one rotated form, but were prevented from repeating the rotated form taken at pretest. Approximately equal numbers of students took each of the rotated forms in both administrations.

One goal of our analysis was to predict posttest achievement as a function of pretest performance plus other determinants. Since students took the core form twice, the core form posttest score reflects, to some degree, familiarity with the core test items. Instead of using the core test, therefore, we analyzed scores obtained from the rotated forms after they were equated to adjust for differences in test length and difficulty. In this analysis, we used equated rotated form formula scores for both pretest and posttest measures of student mathematics achievement. A complete description of the equating procedure is provided in Lockheed, Vail and Fuller (1987).

Student background characteristics

To conform with the value added model outlined above, student characteristics are divided into two categories: time-invariant or fixed (Z_H); and variable or Grade 8-specific (X_H). Fixed background information about each student included his or her sex, age, number of older siblings, maternal education, paternal occupational status, educational aspirations and correspondence between home language and language of instruction.[3] Definitions and summary statistics for each of these variables are provided in Table 1.

Student characteristics thought to vary over the course of the school year include amount of out-of school tutoring in mathematics, perceived parental encouragement, and home use of a four-function calculator (a proxy for family educational resources). Parental encouragement was measured by an index which comprised four items of the type "My mother thinks that learning mathematics is very important for me," with a five-point Likert-type response alternative ranging from 1 = "Exactly like" to 5 = "Not at all like." On this index, a <u>low</u> score represents <u>high</u> parental encouragement.

Peer group, class, teacher and school characteristics

We use three measures of a student's peer group characteristics: average pre-test score, proportion of classmates having mothers with greater than primary education, and proportion of classmates having fathers with professional occupations. No data on actual peer interaction were available for analysis. Class characteristics include class size (number of students), and whether or not the curriculum was described as being "enriched". Teacher background characteristics include his or her sex and participation in in-service training. Teacher classroom teaching practices include using workbooks, maintaining discipline, and administering tests and quizzes. School characteristics include information on regional per-capita income, school size, public/private status, proportion of teachers qualified to teach mathematics, and proportion of teachers who are female. Definitions and categories for these variables are provided in Table 5.

Single-sex learning environment.

In this paper we use the term "single-sex school" to refer to single-sex learning environments: schools, grade levels, or mathematics classes. The achievement effect of single-sex schools is presumably due to the absence of other-sex peers within academic classes. Since many Thai secondary schools are "coeducational" -- that is, they enroll both girls and boys -- but segregate students by sex for instruction, we utilize the segregated learning environment as our indicator of single-sex school.

THE EFFECT OF BACKGROUNT ʼN ACHIEVEMENT IN SINGLE-SEX AND COEDUCATIONAL SCHOOLS

A critical policy question is: Would a student, randomly chosen from the general population, do better in a coeducational or in a single-sex school, and are the effects similar for both male and female students? According to Table 1, the school composition effects for male and female students are quite different. Coeducational schools appear to enhance male achievement, whereas single-sex schools appear to enhance female achievement.

In terms of level, we note that the average scores of boys in coeducational schools are higher than those of boys in single-sex schools, whereas the average scores of girls in single-sex schools are higher than those of girls in coeducational schools, for both pretest and post-test. Moreover, simple gains in achievement (average post-test score minus average pretest score) also appear to favor coeducational schools for boys (3.82 points vs. 2.32 points) and single-sex schools for girls (3.61 points vs. 3.18 points). However, these differences are not as sharp when gain is expressed in units of pretest standard deviation, a common method of comparison. Then, while average male gain in coeducational schools remains greater than that in single-sex schools (half a standard deviation, .51 and one-third of a standard deviation, .32, respectively), female gain is approximately the same in both single-sex and coeducational schools, four-tenths of a standard deviation, with a slight advantage for coeducational schools (.40 and .42, respectively). Thus, it appears that the gross measure of "value added" during eighth grade is clearly higher for boys in coeducational schools, but that the effects for girls are less

Table 1: Background and Achievement in Sngle-sex and Coeducational Schools in Thailand, 1981-82

Variable Description[a]	Male Single	Male Coed	Female Single	Female Coed
Achievement score after 8th grade (A_{i8})	10.50	12.65	14.94	12.19
	(8.46)	(9.05)	(10.62)	(8.82)
Achievement score after 7th grade (A_{i7})	8.18	8.83	11.33	9.01
	(7.29)	(7.57)	(8.95)	(7.62)
Time-invariant background (Z_{μ}), (dummy=1 if):				
Father's occupation:				
unskilled	0.16	0.16	0.12	0.15
skilled	0.39	0.51	0.29	0.46
clerical	0.27	0.22	0.34	0.26
professional	0.18	0.11	0.25	0.13
Mother's education:				
none	0.27	0.31	0.17	0.24
primary	0.53	0.58	0.55	0.63
secondary	0.13	0.07	0.13	0.08
university	0.07	0.04	0.15	0.05
Expectations for further education:				
< 5 years	0.43	0.53	0.27	0.35
5-8 more years	0.35	0.39	0.41	0.45
> 8 more years	0.22	0.18	0.32	0.20
Eldest child	0.24	0.20	0.26	0.22
Language of instruction used at home	0.39	0.50	0.46	0.51
Age in months	172.52	172.12	168.17	170.05
	(9.65)	(8.57)	(8.92)	(8.21)
Private school	0.25	0.10	0.30	0.11
Background during 8th Grade (X_{μ}):				
Hours of extra tutoring	1.54	1.62	1.92	1.64
	(3.20)	(2.63)	(3.66)	(2.54)
Index of parental encouragement (1=high; 5=low)	2.25	2.23	1.90	1.97
	(0.99)	(0.99)	(0.82)	(0.87)
Home use of 4-function calculator (dummy=1)	0.26	0.26	0.37	0.30
Lambda	1.04	-0.53	1.02	-0.47
Number of observations:	567	1,120	502	1,076

[a]Standard deviations in parentheses for continuous variables

consistent. However, because students in coeducational and single-sex schools are also different, these gross figures should not be used to conclude that one school type is more or less effective than the other for either sex.

Students in single-sex schools come from somewhat more advantaged backgrounds than their coeducational school counterparts. This is not surprising given that a higher proportion of students in single-sex schools (27% in comparison with 11% of students in coeducational schools) attend fee-charging private schools. Approximately 21% of single-sex school students (18% of males and 25% of females) had fathers with professional occupations, compared to 12% of coeducational school students (11% of males and 13% of females). Also, a greater proportion of single-sex school students had mothers with secondary school education or above (24% versus 12%); 15% of girls in single sex schools had mothers with some university education. These trends are reinforced by the slightly higher expectations that students in single-sex schools had regarding further education: 22% of the boys and 32% of the girls expected to complete university, as compared with 18% of the boys and 21% of the girls in coeducational schools.

Girls in single-sex schools also benefitted more from parental inputs than their coeducational school counterparts: more home use of calculators, out-of-school tutoring and perceived parental encouragement. A lower proportion of students in single-sex schools spoke the language of instruction at home (39% of male students and 46% of female students as compared with 50% of male students and 51% of female students in coeducational schools). Most of these differences are modest however, and it is not clear from a simple comparison of means how they would affect differences in learning <u>gains</u> (as opposed to learning prior to eighth grade), although they have to be taken into account when comparing achievement scores.

How we control for background

To control for student or household characteristics, such as socioeconomic status (SES) and ability, while comparing achievement test scores, we use the value added achievement model developed earlier. We estimate equation (1) for students in coeducational and single-sex schools separately, under the assumption that they come from different populations[4]:

$$(1a)\quad \tilde{A}_{i8} = \tilde{g}_0 + \tilde{g}_1 * \tilde{A}_{i7} + \tilde{g}_2' * \tilde{X}_{i8H} + \tilde{g}_3' * \tilde{Z}_{iH} + \tilde{e}_{i8}$$

$$(1b)\quad \hat{A}_{i8} = \hat{g}_0 + \hat{g}_1 * \hat{A}_{i7} + \hat{g}_2' * \hat{X}_{i8H} + \hat{g}_3' * \hat{Z}_{iH} + \hat{e}_{i8},$$

where the superscripts ~ and ^ represent single-sex and coeducational sectors, respectively. Note that only household subvectors (subscripted by H) of X and Z are of concern and to simplify notation.

OLS regressions on (1a) and (1b) for coeducational and single-sex school students might lead to misleading results because of the selection bias. Suppose that students and parents are free to choose whichever type of school they prefer. One type of selection results if students sort themselves into those institutions where they think they can perform the best. There would be positive selection in both single-sex and coeducational school samples. Another alternative is that students are hierarchically sorted. For example, if there is excess demand for places into the coeducational schools and the best students are selected, there would be positive selection into coeducational schools but negative selection into single-sex ones. A third alternative is that the selection process operates differently for male and female students. In all cases, the analyst cannot observe the characteristics of single-sex school students among the coeducational school sample or vice versa. Because the subsamples are not a random draw from the student population, the assumptions of the basic linear model and could lead to biased estimates of the achievement effect[5].

To correct for sample selection, we use Heckman's two-step methodology (Heckman 1979). The first step in this methodology is to estimate what determines the choice of type of school (see Cox and Jimenez 1987 for a model of school choice):

(2) $$J_i = k_0 + k_1 Y_i + w_i,$$

where $J_i = 1$ if the ith child learns in a single-sex learning environment, and $J = 0$ otherwise; Y indicates the explanatory variables and w is a random error term.

The second step is to use the results of the first step to correct for the selection bias in (1a) and (1b). If we assume that (w_i, e_i) are jointly distributed, then Heckman (1979) has shown that:

(3a) $$E(e^{\sim}_i \mid I_i > 0) = g^{\sim}_4 * \lambda^{\sim}_i, \text{ and}$$

(3b) $$E(e^{\wedge}_i \mid I_i < 0) = g^{\wedge}_4 * \lambda^{\wedge}_i,$$

where the λ_i's are (Mills) ratios calculated from the first stage probit equation. Including the λ_i's in (1a) and (1b) would enable us to treat the selection bias as an omitted variables problem. The λ_i's times their OLS coefficients g_5's can then be interpreted as the direction and magnitude of selection bias in each of the coeducational and single-sex school achievement equations (see Willis and Rosen, 1979, for a similar treatment). The estimation of (3a) and (3b) by OLS would be consistent (unbiased) because, in theory, the equations hold constant for the probability of being selected in one subsample or another.

What determines the choice of school type?

Previous research on single-sex schooling has suggested that its effects are substantially stronger for females than for males at the secondary level, and one early review concluded that coeducation favored boys and single-sex education favored girls (Lee and Bryk, 1986; Lockheed, 1976). A possible explanation for this is found in studies documenting sex differences in teacher-student and peer interaction in coeducational mathematics classes, which tend to favor males (see Lockheed et al., 1985, for a review covering grades 4-8). Thus, in the present analysis, we have divided the sample by student sex, and have estimated both the choice and achievement functions twice.

As noted above, the first step in the estimation technique is to regress single-sex school choice with variables that measure socio-economic characteristics of the student. The results are presented in Table 2. The most significant variables in determining single-sex school choice for boys are father's occupation, mother's education, home language and whether or not a previous choice had been made to attend a private school. There is a strong preference for boys to choose private, single-sex schools that do not employ their home

Table 2: Choice of Single-sex and Coeducational Schools
Probit Equations (Single-sex =1) for Thailand, 1981-82

	Male		Female	
Variables	Coefficient	t-statistic	Coefficient	t-statistic
Constant	6.62	1.04	6.10	0.90
Father's occupation				
skilled	-0.25	-2.60	-0.18	-1.66
clerical	0.06	0.06	0.11	0.96
professional	0.14	1.11	0.22	1.68
Mother's education				
primary	0.07	0.91	0.05	0.60
secondary	0.40	3.21	0.26	1.85
university	0.40	2.49	0.51	3.31
Educational Expectations				
5-8 more years	-0.08	-1.10	0.04	0.46
> 8 more years	0.05	0.61	0.24	2.53
Age	-0.09	-1.19	-0.07	-0.92
Age squared	0.00	1.29	0.002	0.84
Eldest child	0.09	1.07	0.06	0.69
Language at home	-0.45	-6.61	-0.42	-5.64
Private school	0.75	8.29	0.68	7.32
Number of observations:	1,687		1,578	
Log-likelihood:	-1002.1		-900.3	

language as the language of instruction. Sons of skilled blue-collar fathers are less likely to choose single-sex schools, and sons of mothers with secondary or university level education are more likely to choose single-sex schools.

For girls, the most important background variables in determining single-sex school choice are maternal education, educational expectations, home language and private school choice. Daughters of mothers with secondary or university level education are more likely to choose single-sex schools, and those with expectations to complete college are also more likely to do so. Again, as for boys, girls tend to choose private single-sex schools that do not use their home language as the language of instruction.

The parameters of the probit equations in Table 2 can now be used to estimate the terms that will be used to correct for the selection bias. The average λ in equations (3a) and (3b) are shown in the penultimate row of Table 1.

How does socio-economic background affect school achievement?

The variables that are used to explain achievement scores in Thailand (i.e., the vectors X_{i8H} and Z_{iH}) include many of the same variables that are used in Table 2. However, the variables that represent X_{i8H} should affect achievement scores only, since the decision to select a single-sex or a coeducational school was taken well before the student started eighth grade. This set includes variables that measure parental encouragement for mathematics, out-of-school tutoring during eighth grade, as well as the availability of school aids, such as calculators.

Finally, the achievement equation includes a term that holds constant for the selection bias --i.e., for the probability that a given student will be in single-sex schools. This term is derived from parameters in the choice equation, as described earlier.

The estimated achievement equations (1a) and (1b) are presented in Tables 3 and 4, for male and female single-sex and coeducational school students, respectively. These equations can be used to estimate whether or not a school achievement advantage exists for students in coeducational or the single-sex schools after holding constant for student background and selection.

Table 3: Male Achievement Functions for Single-sex and Coeducational Schools in Thailand, 1981-82

Variable	Coefficients			
	Single		Coed	
	Value	t-stats	Value	t-stats
Constant	16.41	0.41	59.80	1.20
Past achievement	0.68	17.79	0.79	28.94
<u>Time-invariant background (Z_H)</u>				
Father's occupation				
skilled	1.75	2.16	-1.02	-1.69
clerical	2.07	2.38	-0.82	-1.24
professional	2.16	2.19	-0.27	-0.32
Mother's education				
primary	0.99	1.58	0.28	0.64
secondary	-0.22	-0.22	0.05	0.06
university	1.53	1.23	-0.97	-0.87
Educational Expectations				
5-8 more years	0.91	1.46	0.48	1.08
> 8 more years	1.46	2.02	1.80	3.15
Age	-0.07	-0.15	-0.56	-1.03
Age squared	-0.001	-0.05	0.001	0.93
Private school	-2.00	-1.98	0.47	0.50
<u>Background during 8th Grade (X_H)</u>				
Tutoring	-0.04	-0.51	-0.17	-2.30
Parental encouragement	-0.13	-0.47	0.01	0.06
Home calculator	0.51	0.83	-0.24	-0.52
Lambda:	-0.31	-0.17	1.55	0.89
R-squared	0.459		0.481	
F-stats	29.184		63.823	

Table 4: Female Achievement Functions for Single-sex and Coeducational Schools in Thailand, 1981-82

Variable	Coefficients			
	Single		Coed	
	Value	t-stats	Value	t-stats
Constant	-24.68	-0.36	-28.31	-0.75
Past achievement	0.82	20.60	0.78	30.12
Time-invariant background (Z_{ij})				
Father's occupation				
skilled	1.15	1.09	0.05	0.10
clerical	-0.60	-0.55	-0.12	-0.19
professional	0.15	0.12	0.04	0.05
Mother's education				
primary	1.91	2.18	0.32	0.69
secondary	1.56	1.23	1.41	1.72
university	0.78	0.54	0.65	0.58
Educational Expectations				
5-8 more years	0.88	1.11	1.67	3.82
> 8 more years	0.95	1.00	2.16	3.70
Age	0.44	0.55	0.45	1.03
Age squared	-0.001	-0.60	-0.001	-1.21
Private school	-2.57	-2.09	1.31	1.51
Background during 8th Grade (X_{ij})				
Tutoring	-0.04	-0.46	-0.04	-0.54
Parental encouragement	-0.15	-0.38	0.46	2.10
Home calculator	1.81	2.68	-0.13	-0.32
Lambda	-4.65	-1.99	2.34	1.36
R-squared	0.584		0.513	
F-stats	42.587		69.722	

As explained earlier, the interpretation of the coefficients of the stock variables (Z_{iH}) differs from that of the flow variables (X_{iH}). The former are non-marginal effects -- they represent the cumulative effects on past achievement as well. The estimate of the decay rate of the effect on current year achievement of a previous year's characteristic is .68 for single-sex schools; and .79 for coeducational schools. The achievement results will be discussed separately by sex.

Male achievement. For the single-sex school students, paternal occupation (reference category: unskilled) and educational expectations (reference category: less than five more years of school) are statistically significant predictors of achievement. However, maternal educational attainment (reference category: no education), age, tutoring, parental encouragement and presence of a home calculator are all insignificant. Surprisingly, enrollment in a private school is negatively related to achievement gain. For the coeducational sample, educational expectation is the only variable positively and significantly related to achievement gain, and the effect of out-of-school tutoring is negative. The selection term (coefficient of Lambda times its mean) is negative for students in both single-sex and coeducational schools, but the effect is not statistically significant. Thus, for males, the impact of selection on the achievement equation is unimportant.

Female Achievement. For the single-sex school sample, the only background variable that has any statistically significant effect on achievement gain is maternal education (reference category: no education). Presence of a home calculator is significant, but enrollment in a private school is negatively related to achievement gain. For the coeducational school sample the only statistically significant variables are educational expectations and parental encouragement; private schools have no effect on achievement for this group. The selection term (coefficient of Lambda times its mean) is negative for both single-sex schools and coeducational schools, and the effect is significant for single-sex schools.

Background constant, is there a single-sex school effect?

The estimated differential in coeducational and single-sex school students' achievement scores can be computed from the parameters presented in Table 3 to hold constant for the effect of background. We do this separately for male and female students. Because single-sex and coeducational school achievement equations differ in terms of intercept and slope, the comparison would be affected by the values of the other explanatory variables, as well as the coefficients in these equations. To clarify this, we compute the following unconditional single-sex school effect: From the entire sample of single-sex and coeducational students, consider a randomly chosen pupil with the average characteristics of coeducational school students (i.e., standardize according to coeducational school means). The unconditional effect measures the increment (or decrement) in test score had that student been sent to a single-sex school.[6] The same calculations can be performed standardizing at the single-sex school means. The question would be: how would the average single-sex school student have done had he/she been in coeducational school? There is no theoretical reason to prefer one method of standardization over another. However, as in the index number problem, there is no guarantee that the results will be consistent with one another. The results are summarized in Table 5.

Table 5: Single-sex School Effects After Holding Constant for Background Characteristics, Thailand, 1981-82[a]

	Predicted scores of average single-sex school student if that student were in: Single	Coed	Single-sex-Coed Difference
Unconditional effects for:			
Male students	10.81	13.10	-2.29
Female students	19.66	15.84	3.82
	Predicted scores of average coeducational school student if that student were in: Single	**Coed**	**Single-sex-Coed Difference**
Unconditional effects for:			
Male students	11.55	13.44	-1.89
Female students	18.25	13.44	4.81

[a]Calculated from Tables 1, 3 and 4.

The results from the top panel of Table 5 indicate that, after holding constant for past achievement and socioeconomic background, girls in eighth grade single-sex schools have an unconditional advantage in mathematics test performance of about four points and boys have an unconditional disadvantage of about two points. This implies that a Thai eighth grade girl with the background of an average single-sex school student, chosen randomly from the population, would improve her achievement by about 40% by attending a single-sex school, while a boy would reduce his score by 20%.

To check the robustness of this result, we calculated the single-sex school effect for a randomly chosen student with the average coeducational school characteristics. The results, shown on the lower panel of Table 5, are not substantially different.

THE NATURE OF THE SINGLE-SEX COEDUCATIONAL DIFFERENTIAL

The previous section has shown that, in Thailand, girls in single-sex schools score higher in mathematics achievement at the end of eighth grade than do girls in coeducational schools, but that the reverse is true for boys, after controlling for previous achievement, socioeconomic background and systematic selection by school type. For policy makers, the remaining question is, what accounts for these achievement differentials? Is it possible to identify school characteristics that contribute most to these school effects? What do administrators and teachers do that is different? What is the influence of a student's peers on relative achievement?

This section attempts to answer some of these questions for Thailand. The method is to redo the estimates of the previous section. However, this time, the full achievement equation (3) is estimated; that is both $X_{18} = [X_{18H}\ X_{18S}]$ and $Z_1 = [Z_{1H}\ Z_{1S}]$ are included in the equation. We will then discuss how the school-specific components in these vectors of explanatory variables affect achievement in coeducational and single-sex schools.

Differences in School Attributes:

Table 6 presents, by type of school, the mean values of the school, classroom and teacher attributes that will be used in the estimation procedure. They indicate some basic differences between single-sex and coeducational schools. Again, since the single-sex schools were more effective for female students, while coeducational schools were more effective for male students, this section discusses each type of school separately by sex.

Table 6: Characteristics of Male and Female Single-sex and Coeducational Schools in Thailand, 1981-82

	Means and (SD)			
	Male		Female	
Variable Description	Single	Coed	Single	Coed
<u>School-level characteristics</u>				
Average district per capita income in baht	13770.0	12408.0	14951.0	13052.0
	(3311.1)	(4908.3)	(4661.8)	(4944.1)
School enrollment	2024.5	1213.1	1620.6	1290.9
	(1178.6)	(973.7)	(1003.3)	(935.3)
Proportion of teachers qualified to teach math in student's school	0.55	0.53	0.45	0.54
<u>Teacher and class characteristics</u>:				
Teacher's age in years	28.38	29.63	32.35	29.80
	(4.69)	(7.98)	(8.73)	(8.13)
Proportion male	0.50	0.36	0.28	0.28
Proportion having in-service training	0.05	0.12	0.17	0.14
Proportion teaching enriched math class	0.13	0.20	0.24	0.27
Proportion using workbook often	0.17	0.21	0.42	0.23
Proportion spending > 15 mins/week maintaining order	0.72	0.43	0.58	0.43
Minutes/week spent on quizzes and tests	47.96	29.37	35.91	26.79
	(63.13)	(22.76)	(25.51)	(21.57)
Number of students in target class	44.70	41.13	44.00	41.36
	(4.04)	(12.09)	(4.70)	(11.74)
<u>Peer group characteristics</u>				
Average of average pre-test scores	8.18	8.40	11.33	9.47
	(3.72)	(4.27)	(8.95)	(4.70)
Average proportion mothers > primary education	0.20	0.12	0.28	0.13
Average proportion fathers prof occupation	0.18	0.11	0.25	0.13

Males. In comparison with single-sex schools, coeducational schools appear advantaged in one respect and disadvantaged in two others. On the one hand, they are smaller --suggesting greater individualization of program. On the other hand, they are located in poorer regions -- suggesting less access to resources--and have somewhat fewer teachers qualified to teach mathematics.

Characteristics of teachers and their teaching practices, however, generally tend to favor coeducational over single-sex schools. Teachers in coeducational schools are older than those in single-sex schools--suggesting greater experience--and a higher proportion of students in the coeducational sample have teachers who have undergone some form of in-service training. Less time is spent on maintaining order in coeducational classes. A higher proportion of students in coeducational schools are enrolled in enriched mathematics classes and use commercially-produced workbooks; class sizes in coeducational schools are smaller. On the other hand, students in single-sex classes spend more time taking quizzes and tests.

Females. Despite the apparent advantage given to female students by single-sex schools, the schools themselves do not appear particularly advantaged in comparison with coeducational ones. Single-sex schools are more likely to be located in more wealthy regions of the country, to have older teachers and to have students using commercially-produced workbooks. On all other characteristics, they appear disadvantaged relative to coeducational schools. Single-sex schools are larger, have fewer teachers qualified to teach mathematics, have teachers who spend more time maintaining order, and have larger classes.

The rough picture provided by this comparison of means is that schoolcharacteristics might account for male advantage in coeducational schools, but that there are few -- if any --characteristics that explain the positive effects of single-sex schools on female achievement.

School practices and achievement gain

The re-estimation of the student achievement functions includes the additional variables listed in Table 6. As before, single-sex and coeducational school functions are estimated separately. Aside from statistical reasons for not assuming homogeneity of slope and intercept coefficients, separate estimations reflect the fact that unmeasured management practices and "school culture" could differ between coeducational and single-sex schools. Teachers and administrators probably face an entirely different set of constraints, depending upon which type of school they work in. Thus, we expect the coefficients of each of the school or teacher related variables to differ for coeducational and single-sex school students.

The coefficients are presented in Table 7; they demonstrate considerable differences in effects for male and female students and for those enrolled in coeducational and single-sex schools. We therefore again discuss the results separately by sex.

Male Achievement. School level characteristics have greater effects on male achievement in single-sex schools than in coeducational schools. Of the eleven variables examined, seven have statistically significant effects for single-sex school students, while only three have such effects for coeducational school students. In single-sex schools, larger schools and older teachers have positive effects on student achievement. By comparison, student achievement is lower in schools with more qualified teachers, more male teachers, smaller classes, in classes in which the teacher spends more time maintaining order, and in classes considered to have an enriched curriculum. In coeducational schools, teacher qualifications and enriched classes are positively associated with achievement; time spent maintaining order is still negatively associated with achievement.

Table 7: Achievement Functions for Single-sex and Coeducational Schools in Thailand, 1981-82

	Male				Female			
	Single-sex		Coed		Single-sex		Coed	
Variable	Value	T-stats	Value	T-stats	Value	T-stats	Value	T-stats
Constant	10.15	0.26	52.54	1.14	42.83	0.66	-11.09	-0.30
Past achievement	0.59	13.29	0.66	20.96	0.58	12.73	0.66	21.00
<u>Time-invariant background ($Z\mu$)</u>								
Father's occupation								
skilled	2.17	2.69	-0.77	-1.30	0.6[illegible]	0.69	-0.05	-0.09
clerical	1.93	2.27	-0.79	-2.22	-0.62	-0.61	-0.38	-0.62
professional	2.33	2.40	-0.58	-0.68	0.33	[illegible].27	-0.03	-0.04
Mother's education								
primary	0.93	1.51	0.30	0.69	1.42	1.71	0.26	0.57
secondary	-0.671	-0.66	-0.50	-0.56	0.94	0.79	1.15	1.44
university	1.01	0.80	-1.83	-1.62	0.33	0.24	0.10	0.09
Educational expectations								
5-8 more years	0.90	1.47	0.37	0.85	0.59	0.78	1.48	3.47
> 8 more years	0.95	1.32	1.46	2.60	0.91	1.01	1.75	3.04
Age	-0.03	-0.06	-0.51	-0.96	-0.40	-0.52	0.22	0.51
Age squared	-0.002	-0.13	0.001	0.85	0.001	0.41	-0.001	-0.68
Private school	-0.96	-0.89	-0.65	-0.70	-1.36	-1.10	0.01	0.00
<u>Background during 8th Grade ($X\mu$)</u>								
Tutoring	-0.04	-0.54	-0.12	-1.67	-0.03	-0.33	0.02	0.27
Parental encourage.	-0.04	-0.14	0.04	0.20	-0.13	-0.36	0.42	1.96
Home calculator	0.40	0.66	-0.52	-1.12	0.88	1.37	-0.50	-1.21
<u>Peer group during 8th Grade (Xs)</u>								
Average pre-test sco	0.44	4.23	0.41	6.90	0.73	8.24	0.39	7.25
Prop mothers > prim	1.48	0.47	-1.32	-0.46	-3.04	-1.02	1.39	0.50
Prop fathers prof	-3.32	-1.12	1.52	0.62	-4.29	-1.09	-0.21	-0.10
Lambda	-0.50	-0.27	-0.33	-0.19	-1.15	-0.52	1.90	1.01

Female Achievement. Characteristics play an important role in explaining female achievement gain in single-sex schools, but the signs of three of the five statistically significant coefficients are reversed. Thus, positive achievement effects are found for teacher qualifications and larger classes -- both of which were negatively related to achievement in all-male schools-- and negative achievement effects are found for school size -- which was positively related to male achievement in single-sex schools. Inservice training and time spent on maintaining order in the classroom are negatively related to achievement for girls. In coeducational schools, students in enriched classes and those in schools with more qualified teachers score higher on tests of mathematics, while those with teachers who spend time maintaining order score lower.

Is there still a single-sex school effect even after differences in teaching practices and school characteristics are held constant? In order to answer this question, we compute the unconditional single-sex school effect for a randomly chosen student with the average background and the average peer group characteristics of single-sex students. We do this separately for male and female students. According to the first and second panels of Table 8, the achievement advantage of single-sex schools for females is lessened with the addition of teacher and school variables, but there is still a residual effect of two to three points on average. Similarly, the advantage of coeducational schools for boys is maintained. Such differences that remain indicate unmeasured differences between male and female single-sex and coeducational schools that influence achievement and that may have to do with differential peer effects.

Table 8: Achievement Functions for Single-sex and Coeducational Schools Thailand, 1981-82

	Male				Female			
	Single-sex		Coed		Single-sex		Coed	
Variables	Value	T-stats	Value	T-stats	Value	T-stats	Value	T-stats
Constant	30.21	0.77	63.57	1.36	77.58	1.18	-19.39	-0.51
Past achievement	0.63	16.15	0.74	26 25	0.64	14.85	0.75	27.43
<u>Time-invariant background (Z_{μ})</u>								
Father's occupation								
skilled	1.42	1.62	-0.44	-0.71	1.06	0.96	0.08	0.14
clerical	1.63	1.94	-0.65	-1.00	-0.89	-0.87	-0.11	-0.18
professional	2.24	2.35	-0.05	-0.06	0.08	0.07	0.06	0.08
Mother's education								
primary	0.59	0.97	0.30	0.70	1.35	1.61	0.43	0.94
secondary	-0.62	-0.61	0.05	0.06	0.96	0.79	1.43	1.77
university	1.00	0.80	-1.23	-1.10	0.18	0.13	0.95	0.87
Educational expectations								
5-8 more years	0.84	1.36	0.25	0.57	1.32	1.73	1.60	3.71
> 8 more years	1.39	1.94	1.62	2.88	1.78	1.82	2.03	3.50
Age	-0.10	-0.22	-0.62	-1.16	-1.01	-1.31	0.35	0.80
Age squared	0.00	0.07	0.001	1.06	0.003	1.21	-0.001	-0.98
Pivate school	-3.13	-1.64	0.72	0.63	7.08	2.01	1.99	2.00
<u>Background during 8th Grade (X_{μ})</u>								
Tutoring	-0.10	-1.25	-0.15	-1.97	-0.01	-0.16	-0.04	-0.49
Parental encourage.	0.03	0.12	-0.01	-0.03	-0.09	-0.25	0.46	2.12
Home calculator	0.37	0.63	-0.42	-0.90	1.25	1.95	-0.25	-0.61
<u>Grade 8 school characteristics</u>								
District-level per capita income	0.00	0.53	-0.00	1.86	-0.000	-1.46	0.000	0.72
School enrollment	0.002	3.98	-0.00	-0.20	-0.003	-4.84	0.000	0.91
Teacher's math qual.	-4.58	-2.23	1.84	2.55	4.65	2.55	1.51	2.04
Class size	-0.54	-3.15	0.01	0.32	0.93	5.96	-0.02	-1.27
Teacher's age	0.52	5.66	0.01	0.35	-0.10	-1.80	-0.02	-0.50
Male teacher	-4.79	-4.50	-0.11	-0.24	0.49	0.33	-0.24	-0.50
Teach. in-serv. trg.	-2.97	-1.65	0.59	0.91	-10.45	-4.23	0.58	0.96
Enriched math class	-5.57	-4.01	1.86	3.40	-1.48	0.90	1.38	2.74
Used workbook often	-0.11	-0.08	-0.44	-0.86	0.76	0.40	0.13	0.25
Maintain order	-4.31	-4.99	-1.24	-3.00	-4.84	-4.67	-1.45	-3.35
Mins. test/taking	-0.00	-0.03	-0.01	-1.49	-0.06	-1.58	-0.01	-0.71
Lambda	0.77	0.37	1.24	0.69	-3.30	-1.18	3.78	1.93

Peer group effects

Because students interact with each other while in school, the ability and socio-economic status of fellow students could affect individual achievement. Thus, peer group differences could account for the observed single-sex/coeducational school effect differences. However, on average, the peer groups of both boys and girls in single sex schools are more advantaged than those in coeducational schools; mothers are more educated and a higher proportion of fathers have professional employment. Nevertheless, we reran the achievement equations with the addition of three classroom-level variables: average pretest score, proportion of mothers with greater than primary education and proportion of fathers with professional occupations in the school where the student is studying. The results of these regressions are shown in Table 8, separately by sex. They show that average schoolmate pretest score is highly correlated with the individual's posttest score, for both girls and boys, and for both single-sex and coeducational schools.

In order to determine the extent to which peer groups affect the single-sex-coeducational differential, we compute the unconditional single-sex school effect for a randomly chosen student with the average background and the average peer group characteristics of single-sex students. A comparison of the third and fourth panels of Table 9 with that of Table 5 reveals that, for males, the single-sex disadvantage declines to less than one point after peer group characteristics are taken into account, and the single-sex advantage for girls is even further eroded. A similar analysis, standardizing at the coeducational school mean characteristics produces similar results. We conclude that peer groups account for the bulk of the difference in achievement effects between coeducational and single-sex school achievement.

Table 9: Single-sex School Effects After Holding Constant for School Characteristics and Peer Group, Thailand, 1981-82[a]

	Predicted scores at average background of single-sex school student and single-sex school characteristics if that student were in:		
	Single	Coed	Single-sex-Coed Difference
Unconditional effects for:			
Male students	9.73	12.28	-2.55
Female students	18.29	16.15	2.14
	Predicted scores of average background of coeducational school student and coeducational school characteristics if that student were in:		
	Single	Coed	Single-sex-Coed Difference
Unconditional effects for:			
Male students	12.66	13.28	-0.62
Female students	16.88	13.99	2.89
	Predicted scores at average background and peer group characteristics of single-sex school students if that student were in:		
	Single	Coed	Single-sex-Coed Difference
Unconditional effects for:			
Male students	11.01	11.84	-0.83
Female students	16.11	15.73	0.38
	Predicted scores at average background and peer group characteristics of coeducational school characteristics if that student were in:		
	Single	Coed	Single-sex-Coed Difference
Unconditional effects for:			
Male students	11.83	12.48	-0.65
Female students	14.46	13.09	1.37

[a]Calculated from Tables 1, 7 and 8.

CONCLUSIONS

This paper provides evidence regarding the relative effects of single-sex and coeducational school in enhancing eighth grade mathematics achievement in Thailand. It uses pre-eighth grade and post-eighth grade test scores to estimate value added equations for single-sex and coeducational schools, after controlling for the effect of selection into those schools, as well as the direct effect of background on achievement.

Its preliminary conclusions are the following: First, girls in single-sex schools do significantly better than their coeducational school counterparts, after holding constant for selection and background factors, while boys in coeducational schools do better. Thus, there is not a unique single-sex/coeducational school effect on enhancing achievement, but this effect interacts strongly according to the sex of the student.

Second, although we expect that selection biases are mitigated in "value added" formulations of achievement functions (as opposed to "level" formulations), they are still significant in Thailand. Moreover, failure to correct for selection biases results in a singificant underestimate of the positive effect of single-sex schools in enhancing female achievement.

Third, even after measured inputs and school practices are held constant, a single-sex school advantage for females and a coeducational school advantage for males persist.

Fourth, peer "quality" effects in single-sex and coeducational schools appear to account for most of the difference between the two types of schools and their relative effectiveness for male and female students. With the present data, we are unable to explore precicesly how the peer group affects achievement; studies in developed countries suggest, however, that class-level participation rates and leadership opportunities are suppressed for girls in coeducational setting and for boys in single-sex settings, particularly for stereotypically male activities (for reviews, see Lockheed, 1983; Lockheed, 1985). Finally, even after controlling for peer effects, a small residual remains. This suggests that there are important managerial incentives and practices in female single-sex settings and male coeducational settings that result in enhanced achievement.

APPENDIX: THE BASIC VALUE ADDED MODEL

Boardman and Murnane (1979) have shown that, in value-added models, the interpretation of the estimated coefficients and the properties of these coefficients depend crucially on the nature and validity of the assumptions required to derive the estimating equation. Accordingly, we devote the following section to a discussion of the implicit assumptions in our model.

Factors which affect achievement can be quantified through the use of statistical inference. The "ith" pupil's score in the eighth grade mathematics achievement test is characterized by the following equation:

$$\text{(A1)} \quad A_{i8} = a_0 + a_8'{*}X_{i8} + a_7'{*}X_{i7} + \ldots + a_1'{*}X_{i1} + c_8'{*}Z_i + d_8{*}I_i + u_{i8},$$

and the ith pupil's score in the seventh grade test can be similarly expressed as:

$$\text{(A2)} \quad A_{i7} = b_0 + b_7'{*}X_{i7} + b_6'{*}X_{i6} + \ldots + a_1'{*}X_{i1} + c_7'{*}Z_i + d_7{*}I_i + u_{i7}.$$

The symbols represent:

A_{it} Achievement score of the ith child a the end of year $t = 7,8$;

X_{it} A vector of variables describing the ith child's learning environment during year t, such as non-school tutoring, parental encouragement, availability of study materials at home, characteristics of teache , other school-related characteristics specific to year t, peer characteristics; the vector describing learning environment can be partitioned into two vectors, one which is school-related (S) and another which is child or household-related (H), or: $X_{it} = [X_{itS} \quad X_{itH}]$;

Z_i A vector of variables affecting achievement but which is invariant over time, such as the quality of the home environment or parental inputs (such as parents' education), educational aspirations, and student characteristics (sex, age);

I_i A vector of variables describing unobserved influences, such as innate ability or pre-school care;

u_{it} A random disturbance term with a zero mean and variance v^2;

a_t' A vector of coefficients describing the effect on achievement at the end of the eighth grade of a one unit change in the child's environment at year t (e.g., a_7 is the marginal effect on eighth grade achievement of environmental characteristics during the seventh grade);

b_t' A similar interpretation as the a's for achievement at the end of the seventh grade;

c_t' A vector of coefficients of the marginal effect on eighth grade achievement of a unit change in one of the Z variables;

d_t The marginal achievement effect of the unobserved component;

' Indicates a transposition of a column vector into a row vector.

It is not feasible to estimate equations (A1) and (A2) because researchers rarely have much information on past characteristics, such as class size or parental tutoring four or five years before. An alternative is to estimate (A1) and (A2) as "value added" equations by subtracting (A2) from (A1) (see Hanushek 1986 for a more thorough review of the arguments). The resulting equation could greatly simplify the specification if some of the X_{it}'s cancel each other out. However, for this to happen, additional assumptions are necessary. Boardman and Murnane (1979) have demonstrated the importance of deriving the empirical form of the "value added" equations carefully since each specification imposes behavioral restrictions.

The specifications in (A1) and (A2) imply that school and student characteristics in previous years also affect current achievement. For example, the size of a student's class in the seventh grade (on down to the 1st grade) affects his/her eighth grade achievement. However, we do not expect characteristics in previous years to have the same effect on current period achievement as current period characteristics. A more reasonable expectation is that the effect of past characteristics on current achievement diminishes over time. If this effect diminishes geometrically, then, a simple "value added" equation can be derived from equations (A1) and (A2).

Let the unsubscripted variables "a", "c", and "d" represent the "true" current period effect of a component of X, Z and I, respectively, on school achievement. For example, "a" is the marginal effect of an increase in one unit of class size during the eighth grade on eighth grade achievement. Thus, $a_8 = a$. Let f be the amount by which the effect of seventh grade characteristics on eighth grade achievement diminishes relative to a, or $a_7 = f*a$.[1] The critical assumption is that the effect of previous years diminishes geometrically thereafter.

[1]We would expect $f < 1$. However, this is not a restriction since f is a parameter to be estimated. In the unlikely event that the estimated $f > 1$, we conclude that past characteristics have greater importance than present characteristics in explaining present achievement.

Or, $a_6 = f^2*a, \ldots, a_1 = f^7*a$, for $f < 1$. By similar reasoning, the impact of previous years' characteristics on 7th grade achievement is: $b^7 = a, b^6 = f*a, \ldots, b_1 = f^6*a$. These definitions can then be substituted into (A1) and (A2).[2] Then, if (A2) is multiplied by f before it is subtracted from (A1), and terms are cancelled out, the following simple specification is obtained:

$$\text{(A3)}\quad A_{i8} = g_0 + g_1*A_{i7} + g_2'*X_{i8H} + g_3'*Z_{iH} + e_{i8}$$

where $g_0 = (a_0 - f*b_0)$, $g_1 = f$, $g_2' = a'$, $g_3' = c'*(1-f)$ and $e_{i8} = d'*(1-f)*I_i + (u_{i8} - f*u_{i7})$. This estimating equation is intuitively appealing because the terms describing previous environments X_{it}, $t=1,\ldots 7$, are deleted and the (unrestricted) coefficient of A_{i7} can be easily interpreted as f.

[2]The properties of this lag structure are well known in the applied econometrics literature.

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Footnotes

1. Modern statistical techniques help in controlling for this bias, altlough recent research has revealed that it is also important to keep track of one's assumptions in modelling (see Murnane, Newstead and Olsen, 1985, for a careful assessment of the results of Coleman et al. and their critics). Moreover, it is not possible to measure all relevant characteristics; apparent differences by school type, therefore, could be due to some unmeasured aspect of the student's background, ability and/or motivation. Several studies have attempted to use direct measures of ability through the use of tests specifically designed to measure innate ability (e.g., an I.Q. test) rather than cognitive achievement (Psacharopoulos and Loxley, 1985; Boissiere, Knight and Sabot, 1984 among others). Many analysts have questioned the validity of these tests in distinguishing between ability and achievement. In any case, no one has ever suggested that such tests fully control for both ability and motivation.

2. This section draws heavily from "Thailand" in the International Handbook of Educational Systems (Cowen & McLean, 1982), pp.515-555.

3. Since the correlations between paternal and maternal occupational status ($r = .39$) and paternal and maternal educational attainment ($r = .58$) were high, we analyzed the effects of paternal occupational status and maternal educational attainment only. There were also fewer missing cases for these variables.

4. Alternatively, equation (1) can be estimated as one equation, with a dummy variable for single-sex and coeducational types of schools. However, statistical (F-) tests lead us to reject the

hypothesis that the coefficients of all the other variables are equivalent in both types of schools. Results are available from the authors.

5. The presence of I as a component of e is the critical factor in this problem. If there were no unmeasurable influences on achievement, or if unmeasurable effects were uncorrelated with school type, as well as other components of Z and X, there would be no selection bias. Present samples would be random draws from the population. Of course, costly strict experimental designs would also obviate this problem -- i.e., if students were assigned randomly to coeducational and single-sex schools.

6. This unconditional effect nets out the selection term from both the coeducational and single-sex equations in calculating school effects. In contrast, the conditional single-sex school effect would measure the following: from the sample of students who have already selected coeducational school, the increment (or decrement) in test scores had that student gone instead to a coeducational school. This conditional effect leaves in the selection term in calculating school effects.

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